Reforming the Eighth-Grade Student Assignment Process for the Philadelphia Public Schools

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Abstract:
The eighth-grade student assignment project is an initiative of the School District of Philadelphia that assigns students to high school academic programs based on student preferences, academic preparation, program capacity and desegregation requirements. This paper describes recent modifications to the eighth-grade student assignment process that resulted in: a comprehensive, realistic description of business processes, a new, more accurate method for recording family preferences and modifications to the student assignment process that better reflects student preferences and system constraints. We describe other recommendations not yet implemented, including more flexible program reporting to families, a relational database to meet future student processing needs, customer service via the Internet and management science models to automate the assignment process.

Keywords: Education, Decision Support, Internet, Policy Analysis

I. Introduction

The School District of Philadelphia (SPD) has for the past four years been engaged in a process to fundamentally change the process by which children are educated in the city of Philadelphia. Called Children Achieving [School District of Philadelphia, 1995], this initiative addresses the following key strategies: (1) high academic expectations for all children, (2) design and implementation of performance measures to assess student progress, (3) reducing the size and role of the central administration and increasing the flexibility and accountability of local schools, (4) ensuring that students entering the educational system are ready to learn, (5) increasing community supports and services to students, (6) providing up-to-date instructional and administrative technology, (7) engaging the public in dialogue regarding educational strategies, and (8) ensuring the availability of adequate financial resources to be used effectively.

In this paper we describe a project called the Eighth-Grade Student Assignment Process that focuses on the third, sixth and seventh strategies. One important aspect of decentralizing authority in the Philadelphia public schools is the increased responsibility of comprehensive high schools to design academic programs that address specific needs of students and train them for well-identified careers in various areas, including college preparation. These programs, called small learning communities (SLCs), focus on areas such as design and technology, communications, business, health and so on and draw primarily from students in local, feeder middle schools. SLCs have two main goals: to complement existing offerings in Philadelphia's area vocational/technical high schools (AVTs) and selective admissions programs and high schools (SAs) which draw from a citywide admissions pool, and to ensure that students who need academic support in
smaller, more personalized environments can flourish. Because parents are provided with additional choices for academic programs with limited capacity, a procedure has been developed to enable students to apply for various SLCs, AVTs and SAs and for SPD to allocate students to programs that best match their preferences. The *application and lottery process* is a combination of applications, data entry, student evaluation and random selection of qualified applicants for various programs. The lottery process has historically been performed using mainframe-based COBOL programs operating on non-relational databases.

The eighth-grade student assignment process was revised for two reasons. First, the expansion of the lottery process from AVTs and SAs to include SLCs required a re-thinking of the application and data management processes. Spaces in certain high school programs are very valuable, and SPD anticipated significant difficulty managing the increased volume of applications given the inclusion of SLCs in the planning process. Previous experience with public debates regarding students not admitted to programs they thought should have accepted them made SDP anxious to ensure that the expanded application and lottery process would be fair and be perceived to be fair to all applicants.

The author, along with a cross-disciplinary team of SDP personnel, designed a revision to the application and lottery process that resulted in the following improvements: (1) a comprehensive, realistic description of business process flows, (2) a new method for recording family preferences, (3) a new method for performing student lotteries and post-lottery analysis, (4) a new process for meeting management reporting needs, and (5) a design for a relational database to meet future student information processing needs. We believe that the improved application and lottery process for eighth-grade students,
implemented for academic year 1998-99, has resulted in the following: increased level and perception of family choice in high school academic programs; increased awareness on the part of local school administrators of the need to design academic programs to attract students; increased awareness on the part of policy-makers and information technology analysts alike of the need for modern information technology applications to store, analyze and disseminate data related to application and lottery process inputs and outcomes; and exposure to the notion of decision models to optimize, at least in part, the assignment of qualified students to most-preferred academic programs.

Section 2 places the student transfer process in the context of contemporary scholarly discussions of school choice, restructuring and the use of information systems for improved school administration. Section 3 of this paper presents initial efforts by the School District of Philadelphia to increase choice for academic high school programs, practical constraints to providing popular academic programs in an equitable manner and the role of information technology in facilitating the eighth-grade transfer process. Section 4 presents the innovations of the eighth-grade assignment project in terms of business process re-design, information management and student assignment algorithms. Section 5 describes how recommendations from this project were actually implemented for the 1998-99 school year. Section 6 presents a variety of extensions to the eighth-grade student assignment project that would further enable SPD to meet the needs of parents and students. Particular attention is paid to the untapped role of relational databases and the Internet for providing historical and current information to improve parental decisionmaking, and the role of operations research/management science in designing
mathematical models for student allocations to optimize various objectives of interest. Section 7 concludes.

II. Education Policy and the Student Assignment Process

The eighth-grade student assignment process is an example of a limited form of school choice as implemented by the School District of Philadelphia. The Carnegie Foundation for the Advancement of Teaching [1992] defines school choice as the ability of families of children attending public schools to choose among alternative public academic programs within their school district ("districtwide choice"), alternative public academic programs throughout the state in which they live ("statewide choice") and alternative public and private academic programs ("private school choice" or "voucher plans").

School choice is a hotly debated topic, with analysts such as Boaz [1991], Chubb and Moe [1991] and Peterkin [1991] advocating the full range of choice plans as key to spurring public schools to produce better quality programs, the Carnegie Foundation for the Advancement of Teaching [1992] positioning choice as consistent with the desires of the minority of parents who want such options but insufficient, in itself, to produce systemic change in public education, and Nelson, Carlson and Palonsky [1993] presenting arguments from both sides of the debate. Researchers such as Murphy [1993] and Hallinger and Hausman [1993] have conducted case studies demonstrating the challenges associated with school restructuring and school choice in particular and argue that school-level reforms are essential to making choice policies succeed. While there is relatively little documentation on the view of the School District of Philadelphia itself regarding choice or educational outcomes associated with choice, anecdotal evidence collected by this author
indicates that administrators a limited form of district-level school choice as essential for retaining the confidence of parents of students in the Philadelphia public schools and thus worthy of the business process redesign effort that is the subject of this paper.

The literature on administrative tools applicable to school choice is sparse. The text by Lunenberg and Ornstein [1991], which appears typical of offerings in this area, has little to say on school choice and focuses instead on administrative strategies to deal with financing, school closings, building renovations and related topics.

The literature on management information system applications that might be specifically relevant to implementation of school choice appears sparse as well. An introductory text on information systems for school administrators [Picciano, 1994] has little to say about MIS beyond standard applications for test scoring, energy management and automated telephone calling systems. Song [1992] presents a MIS application to assist administrators in choosing effective educational programs. However, there are a number of studies that address the general issue of design and implementation of MIS for public school systems. Reneke [1994] makes the case for a long-term commitment to change and public access to information to make better decisions when transitioning from mainframe-based systems to client-server systems. Bracci [1999] addresses similar planning issues for implementation of information technology in the classroom. Barrett [1999] examines the level of understanding of school administrators regarding MIS and concludes that extensive training and a view of MIS implementation as a triad of awareness, expectation and perception is crucial is necessary for MIS applications to enhance administrator productivity.
Based on this brief survey of the educational policy and MIS literature, there appears to be little published information on the particular type of choice program embraced by the School District of Philadelphia, and little guidance on the type of business processes and MIS implementation that could best contribute to the success of the eighth-grade assignment process. Subsequent sections of this paper will thus describe this choice program, the modifications made to the business process and the IT implementation in detail.

III. Small Learning Communities and the Existing Student Assignment Process

The School District of Philadelphia is divided into 22 clusters, or pre-defined geographic areas, that contain neighborhood elementary schools, middle schools and comprehensive high schools (see Figure 1). All students residing in a particular cluster (with exceptions for some students with special needs or those for whom English is a second language) are guaranteed a spot in the local schools. The collection of elementary and middle schools in a particular cluster defines a feeder pattern to the local comprehensive high school.

In addition to neighborhood-based schools, SDP has a number of elementary, middle and high schools that accept students from across the city. Some of these schools are area vocational/technical high schools (AVTs) and others are special admissions high schools (SAs), both of which admit students based on academic qualifications beyond minimum requirements.
Traditionally, all local schools could accept students from inside the feeder pattern and, if space permitted, students from outside the feeder pattern. Comprehensive high schools had generally undifferentiated academic offerings for students without special needs, although some offer special programs for e.g. college-bound students. This resulted in a lack of programmatic flexibility for those students who did not attend AVTs or SAs. Combined with the limited number of slots at AVTs and SAs, and the perceived low level of academic quality at comprehensive high schools compared to AVTs and SAs, increasing numbers of parents have reacted by moving their children to private and parochial schools.


Figure 1: School District of Philadelphia Clusters
The Children Achieving initiative may be seen in part as a reaction to this dissatisfaction with conventional academic offerings.

Small Learning Communities (SLCs) were devised as a way to increase the variety of academic offerings to students with a wide range of interests, academic strengths and special needs (see Table 1 for examples of SLCs within comprehensive high schools). SLCs fall into three categories determined by the method of student acceptance. Some are open enrollment—all students who apply are accepted. Others are criteria-based—students must express an interest in the program, via an essay or interview, and must meet certain minimum academic and disciplinary requirements. Still others are special admissions-based—students must meet certain minimum requirements for consideration for admission and SLC administrators can select from the subset of minimally qualified students those who will enter the program. While all SPD comprehensive high schools have SLCs, most of these programs are open enrollment.

While every student in a comprehensive high school’s feeder pattern is guaranteed a slot in the local comprehensive high school—and perhaps in a particular SLC—parents and students are encouraged to evaluate the range of SLCs offered to choose one best matching the interests and abilities of students. In addition, students are encouraged to apply to any SLCs—within the local feeder pattern or not—that interest them. Thus, schools are encouraged to devise academic offerings that meet student needs and result in beneficial academic outcomes, or face the possibility of losing enrollment.
<table>
<thead>
<tr>
<th>School</th>
<th>Open Programs</th>
<th>Criteria-Based</th>
<th>Special Admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lincoln</td>
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<td>Design and Technology</td>
<td>Business Technology</td>
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<td>Fast Track at Swensen</td>
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<td>M.L. King</td>
<td>Auto/Computer Engineering (ACE)</td>
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<td>Scholarly Magnet</td>
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<td>Travel and Tourism (CIS)</td>
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<td>HRT Academy</td>
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<td></td>
<td>...</td>
<td>Hi-Tech SLC</td>
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</tbody>
</table>

Table 1: Examples of Small Learning Communities Within Comprehensive High Schools

The task then fell to the Office of Standards, Equity and Student Services (OSESS) of SDP to devise an application mechanism to determine which eighth-graders, facing the choice of SLCs, AVTs and SAs in the following year, would be assigned to which program. For the 1997-98 school year, SDP modified an application process originally intended for AVTs and SAs alone by which students could simultaneously express interest in various programs and submit their academic qualifications. This process required that parents and students fill out up to three forms—one for SLCs, another for AVTs and a third for SAs. SDP would then collate the various forms, enter them into the district information system, and send student information to the various programs. Students would first be deselected, i.e. removed from the pool of potential students, if they did not meet minimum qualifications for the academic program. Next, the Information Technology (IT) Department of SDP would run a series of computer programs (dubbed the lottery) to assign
students to their most-preferred programs, or, if there was insufficient space for all qualified applicants, devise a waiting list from which applicants would be randomly selected as spaces for particular programs opened up. Due to public school desegregation requirements, and the requirement that local (inside-feeder) students get priority for SLCs, for each SLC lotteries were conducted for four groups of applicants: inside-feeder whites, inside-feeder non-whites, outside-feeder whites and finally outside-feeder nonwhites.

Parallel to this process, SAs, which had complete control over their admissions processes, and AVTs, which have somewhat less control, would evaluate potential students and devise waiting lists and pools of admitted students on their own. When SLCs, AVTs and SAs made their preliminary admissions decisions (to admit, put on a waiting list or not to admit), SDP would communicate these decisions to parents, who would then choose the single program into which the student would enroll.

This procedure suffered from a number of serious flaws. First, parents had very little knowledge about the various academic programs, especially the SLCs. In particular, there was little information available about the number of slots available to inside-feeder and outside-feeder students and little information about the popularity of various programs. Thus, parents had little guidance as to the likelihood that their children might be accepted to various programs.

Second, the multiplicity of forms resulted in many incomplete or multiple copies of forms for the same student submitted to SDP. In particular, parents reasoned, incorrectly, that submitting multiple forms would increase their children’s chances of being admitted to certain popular programs.
Third, IT’s software used to run the lottery was written in COBOL and used data stored in variable-length data tables stored on a mainframe. The exact algorithms used were known only to a very few, and the programs took a long time to run. Limitations of the software and hardware resulted in inefficient data storage schemes, an inability to construct an audit trail for admission decisions resulting from the lottery, and a relatively high incidence of programming bugs that made the lottery process longer than necessary. This limitation led to the fourth major problem: the complexity of the lottery process and the high level of user intervention increased the likelihood that certain students might not be admitted to programs that were their most-preferred and for which they were qualified, and that certain other students might be admitted to programs that were not their most-preferred or for which they did not qualify.

Finally, as the Children Achieving initiative was ongoing, the number of SLCs was forecast to increase significantly in upcoming years, putting even more pressure on SDP, and in particular IT and OSESS, to manage the increased demand for these programs.

IV. Policy and Technical Modifications

The eighth-grade student assignment process was modified in three specific ways by a team composed of SDP staffers from the Office of Information Technology, Office of Standards, Equity and Student Services, Office of Student Placement and Office of Assessment and Accountability, and the author. First, the existing business processes behind the assignment process were mapped onto a process flowchart, enabling staffers to identify bottlenecks and to set realistic due dates for task completions. Second, high school program application forms was redesigned to allow parents to fill out a single form for all
academic programs, including preferences for SLCs and AVTs. Third, the process by which student applicants were assigned to academic programs was modified to better enable SDP to respect student preferences and program capacities. Results from implementation of these changes are examined in Section 4.

In addition, proposals were made, but not yet implemented, to make the creation of management reports regarding the student assignment process easier and more flexible for non-technically-skilled staff, to design and implement a relational database for student information to augment or replace the current mainframe-based system, and to make historical information regarding the student assignment process more accessible to parents and students. These proposals are examined in Section 5.

Mapping and modifying the business processes associated with student assignment required, first, a common, cross-team understanding of the “big picture” as well as the process at a more detailed level. At the highest level, as shown in Figure 2, the student assignment requires inputs composed of academic and preference information from the student and his/her family, capacity and feeder patter information from SDP, and produces outputs composed of actual academic program assignments used by the student and his/her family and by the SDP student information system.
A more detailed view of the student assignment process, shown in Figure 3, illustrates the following key steps. First, student applications to academic programs are entered into the SDP information system. Second, the list of applicants is reduced by excluding students that do not meet minimum requirements for various programs. Third, the reduced list of student preferences for SLCs and AVTs are input to the student assignment lottery process while, in parallel, SAs make acceptance decisions. Fourth, modifications are made to lottery results for students not assigned to any SLC. Fifth, parents and students are notified, in most cases, of initial assignment decisions and asked to choose a single program to which a student will register for the upcoming fall. Finally, program choice information from parents, and, if necessary, manual assignments for hard-to-place students are input to the student information system.

Figure 2: High-Level View of Student Assignments
As indicated earlier, application forms for the student assignment process for academic year 1997-98 were considered to be overly complex. The main problem with the old process was that parents were expected to fill out one form for each set of SLCs, AVTs and SAs for which they were interested and to rank, separately, their preferences for the various SLCs and AVTs. Parents also had to review and possibly modify three separate student data forms listing performance in academic classes and standardized tests. It was then left to the Office of Information Technology to enter data from these separate forms into separate data structures, with obvious redundancies. OIT also had to reconcile the different preferences without knowledge of how families might rank the various academic programs together, potentially wasting processing time on most-preferred programs in categories that were really not, overall, of great interest to parents. Finally, parents, knowing that students were selected for very popular programs using a lottery process,
reasoned that their children’s chances for acceptance would be increased if they filled out multiple applications. Again, OIT was burdened with the task of culling duplicate application forms for three separate programs, a tedious and manpower-intensive process.

From the beginning of the project our goal was to design a single application form for SLCs, AVTs and SAs that would minimize duplication in data entry and storage and best represent parent and student preferences for the various academic programs, focusing interest on the key distinctions between inside-feeder and outside-feeder programs, and open-enrollment and criteria-based programs versus special admissions programs.

The reasons for these distinctions are the following. First, since the majority of SDP students are (1) guaranteed spaces at open enrollment academic programs at their neighborhood comprehensive high school and (2) likely to enroll in programs, open-enrollment or criteria-based, at their neighborhood comprehensive high school due to simple proximity, programs in these high schools have reserved the majority of their program spaces for students living in the local feeder pattern (“inside-feeder”), and a smaller fraction of program spaces for students living outside the local feeder pattern (“outside-feeder”). Second, since the majority of SDP students are insufficiently prepared academically for special admissions programs, it is important to distinguish between SAs and non-SAs, especially if a particular SA is housed within an applicant’s local comprehensive high school.

Thus, the new High School Admissions Form (HSAP; see Appendix 2) groups academic programs in three categories: inside-feeder (both open-enrollment and criteria-based programs), outside-feeder (both open-enrollment and criteria-based programs) and special admissions programs (both inside-feeder and outside-feeder). In addition, the
HSAP explicitly mentions that the outside-feeder and special-admissions sections of the form are *optional*, recognizing that parents should, at the very least, select, from among the inside-feeder programs to which their child is most likely to be admitted, those that are most preferred.

In both the inside-feeder and outside-feeder sections, parents are asked to rank academic programs in descending order of preference. (Parents are *not* asked to rank special-admissions programs in order of preference because in this case the process of selecting candidates is entirely within the discretion of the SAs.) Then, parents are asked to aggregate their preferences by listing the four most-preferred programs (two inside-feeder and two outside-feeder programs). This process was intended to assist parents in refining their preferences for those programs students are most likely to be accepted.

We now examine the actual process by which students are assigned to academic programs based on the HSAF. This process was modified as a result of changes to the HSAF and also to reduce politically sensitive instances of students not receiving admittance to most-preferred programs even if they could prove that other students, for whom a particular program was *not* their most-preferred, were admitted anyway.

Recall that applicants can be deselected (removed from consideration) from criteria-based programs if they do not meet minimum requirements, thus we consider only those students that qualify for criteria-based programs. Denote by \( i = 1, 2, \ldots, N \) the set of non-SA programs\(^1\) and denote by \( s_i \) the number of slots available for program \( i \). Denote by \( L^1_i \) the set of students who have listed non-SA program \( i \) as their most preferred program, \( L^2_i \) the set of students who have listed program \( i \) as their next-most-preferred program, and

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\(^1\) By "non-SA program" we treat slots for inside-feeder vs., outside-feeder and white vs. black applicants as separate programs.
so on. Students in each list $L^i_j$, $j = 1, 2, \ldots, P$ for some maximum preference list size $P$ are randomly sorted so as not to give undue advantage to those who have applied earliest. For each non-SA program $i$, the initial lottery considers only students on lists $L^i_1$ for preliminary acceptance: students in $L^i_1$ whose random ranking do not exceed program capacity are granted preliminary acceptance to programs. Students in $L^i_1, L^i_2, \ldots$ whose random rankings exceed program capacity are put on a “virtual waitlist”. In parallel to this process, AVTs and SAs make initial acceptance decisions\(^2\).

After initial lottery and special admissions programs determinations, students fall in different categories:

- Those who have been accepted to their most-preferred inside- and/or outside-feeder SLC and at least one SA program (Category A)\(^3\);
- Those who have been accepted to their most preferred inside- and/or outside-feeder SLC, have been accepted to no SA programs, but are on the waiting list for at least one SA program (Category B);
- Those who have been accepted to their most preferred inside- and/or outside-feeder SLC, have been accepted to no SA programs, and are not on the waiting list for any SA programs (Category C);
- Those who have not been accepted to their most preferred inside- and/or outside-feeder SLC but have been accepted to one or more SA programs or are on the waiting list for one or more SA programs (Category D);

\(^2\) AVTs and SAs usually approve more students for admission than there are available slots, knowing that some of these students will choose to enroll in other programs. This issue is examined in more detail further in the section.
Those who have not been accepted to their most preferred inside- and/or outside-feeder SLC, have been accepted to no SA programs, and are not on the waiting list for any SA programs (Category E);

Those who have not returned the HSAF (Category F).

SPD will communicate with certain families post-initial lottery, depending on the initial disposition of that family’s child:

- Categories A and C: The family receives a letter, called a Multiple Acceptance Report (MAR) listing all program acceptances and a request to choose a single program for admission in the fall. A family’s choice in this situation is final and cannot be rescinded.
- Category E: The family receives no correspondence from SPD. SPD will attempt to provide the child with his/her highest-preference SLC after a reconciliation phase.
- Category F: The family receives no correspondence from SPD. SPD will manually place the child in an inside-feeder, open-enrollment program after the reconciliation phase.
- Categories B and D: The family receives no correspondence from SPD and awaits final disposition of SA applications.

3 SA criteria are so similar that most students who meet the criteria for one program more than likely can be approved for all programs.
After families in categories A and C accept admission to a student’s particular program, that student’s name is struck from *all other* SLC program lists. This opens up slots for other children who were not admitted to programs in the initial lottery.

After processing Multiple Acceptance Report responses, a student has either:

- Accepted admission to his/her first-most preferred non-SA program, or
- Accepted admission to an SA program, or
- Chosen to await SA waiting list dispositions, or
- Been denied admission to his/her most-preferred SLC and has been denied consideration for SA programs.

It is the last two groups whose needs SPD attempts to meet in this phase. To provide order to the reconciliation process, non-SA programs with open slots are considered in random order first for students for whom the program is outside their feeder, and second for students for whom the program is inside their feeder. (Certain programs are considered twice in this scheme). For a particular non-SA program $i$, after spaces appear in the list $L^i_1$ of applicants for which program $i$ is their most-preferred, students remaining on $L^i_1$ but not yet admitted fill open slots in randomized sequential order until either:

- All eligible students in $L^i_1$ receive admittance to the program, or
- All available slots for the program are filled.
Students in \( L^i_1 \) who have not been admitted to any SA programs have their names stricken from consideration for all other non-SA programs \( k \neq i \) in which they have expressed interest immediately after their admissions occur. These admissions, considered to obey student preferences, are final and cannot be rescinded. Note that families have no choice in this admission process. In addition, some students on SA waiting lists (and, possibly, in \( L^i_1 \)) are subsequently accepted by one or more SAs. These families then choose between one of the SAs (and, possibly, non-SAs) to attend. These students’ names are stricken from all non-SA waiting lists as well, freeing up yet more space in non-SAs for students not yet accepted to their first-most preferred non-SAs.

After lists \( L^i_1 \) for all programs \( i \) have been considered, and updated, in the reconciliation phase, practically no students not yet admitted to their first-most-preferred non-SA programs can ever be so admitted in the future. So consideration now shifts to students’ second- and lesser-preferred programs. Post-MAR reconciliation is now repeated for those students who have not yet been admitted to any non-SA programs, in descending order of student preference.

A problem with the algorithm described above is that, given the amount of human intervention in this process, it is still possible for students to be assigned to their second- or less-preferred non-SA programs even if space becomes available in their first-preferred non-SA program. It is possible that operations research/management science algorithms could more consistently allocate students to programs based on expressed preference requiring minimal human intervention in the form of post-MAR processing.

Two consequences of this admissions process are that (1) some non-SA programs may have higher-than average concentrations of students for whom the program was not
their first-most preferred program, an indication that these programs should work to make themselves more desirable, and (2) some teacher reallocations may be necessary to ensure that every student does have a slot in a (possibly less-preferred) local program.

V. Implementation of Recommended Changes

In this section we examine the experiences of SDP in implementing the changes described in the previous section for the academic year 1998-99. In general, SDP has found that the student transfer process has proceeded quite smoothly so far, even as deadlines for various processes were advanced substantially. Unfortunately, no effort was made, to the author’s knowledge, to collect data specifically to enable the modified student transfer process to be formally evaluated.

An initial change to the planned student transfer process occurred when, to coordinate special admission program acceptances and lottery processing, the deadline for completion of the high school transfer process was advanced from April 23, 1999 to March 10, 1999, as indicated in Appendix 1. This required data entry of initial student applications to be completed much earlier than anticipated, resulting in substantial overtime and outsourcing costs incurred by SDP. However, from this experience SDP learned that outsourcing the data entry process may lead to potential future economies in this area.

The high school transfer program was widely publicized throughout Philadelphia in the months leading up to the application deadline data of November 20, 1998 via citywide fairs and presentations at local high schools. SPD’s preliminary assessment is that a large majority of families with children entering high school had a substantial understanding of
the variety of academic program choices they faced and filled out the High School Admissions Form correctly. However, a lack of historical information about trends in student acceptance rates for various programs, and a lack of public information regarding the forecast number of inside-feeder and outside-feeder slots to be made available made it difficult for families to make most-informed choices for space-limited and academically rigorous high school programs.

The primary change to the processes described in the previous section concerns the actual lottery process. As Table 2 indicates, for two of the three high schools listed, the number of out-of-feeder SLC applicants not deselected initially far outstrips available capacity. This is a consequence of the fact that most neighborhood comprehensive programs that do not draw from a citywide student applicant pool have very few openings for outside-feeder students. (For the third high school, the number of outside-feeder slots is a consequence of the low inside-feeder enrollment, as many students in that high school’s cluster attend private or parochial schools.)

Also of interest is the large number of applicants, both inside-feeder and outside-feeder, who are removed from consideration for the criteria-based SLCs in the first and third high schools listed below. This is an illustration of the fact that the current achievement level of many SDP students excludes them from consideration for non-open-enrollment programs. However, the demand for such programs is substantial, indicating that incentives exist for students currently in the seventh grade to improve their academic performance to be considered for criteria-based programs in the coming year. (Again, the relatively large numbers of students accepted for consideration for SLCs in the second high school is a function of that school’s need for students to fill excess capacity.) Table 2
indicates that in general, given high demand for outside-feeder SLC slots, i.e. that $L_1^i$ substantially exceeds $s_i$, only students for whom these programs are most-preferred will be admitted. On the other hand, many students in $L_1^i$ will not be admitted to program $i$, thus it will be necessary to consider their second- or lower-ranked choices, or, at worst, assign them to an open-enrollment SLC in their local comprehensive high school.

<table>
<thead>
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<th>High School /SLC*</th>
<th>Available Regular Education Slots</th>
<th>Number of Students Applied/Deselected</th>
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<tr>
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<td>Inside-Feeder</td>
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<td>HS#1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SLC1</td>
<td>85</td>
<td>6</td>
</tr>
<tr>
<td>SLC2</td>
<td>85</td>
<td>6</td>
</tr>
<tr>
<td>SLC3</td>
<td>85</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HS#2</td>
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<td></td>
</tr>
<tr>
<td>SLC1</td>
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<td>140</td>
</tr>
<tr>
<td>SLC2</td>
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<td>100</td>
</tr>
<tr>
<td>SLC3</td>
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<tr>
<td>HS#3</td>
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<td></td>
</tr>
<tr>
<td>SLC1</td>
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<td>0</td>
</tr>
<tr>
<td>SLC2</td>
<td>56</td>
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<td>0</td>
</tr>
<tr>
<td>SLC4</td>
<td>97</td>
<td>15</td>
</tr>
</tbody>
</table>

*Note: High School and SLC names suppressed for confidentiality

Table 2: Criteria-Based SLC Program Availability for First-Choice Applicants

Another area of interest regards student admissions to AVTs and SAs. Because students who are admitted to a single AVT (SA) are likely to have been admitted to all AVTs (SAs) to which they have applied, AVTs and SAs must account for the fact that the number of students approved for their programs can exceed substantially the number of students who actually enroll. The number of students approved for AVTs/SAs is called the
"yield factor" (technically a yield factor would equal (# available slots ÷ # students qualified for admission)). Since students are allowed to rank the AVTs for which they have applied by preference, AVTs use a lottery to choose from the number of students meeting minimum qualifications for admission a smaller number of students likely to consider enrollment in the AVT. From this smaller number of qualified students it is hoped that the number of students who accept that AVT matches the number of slots available. Because SAs are not ranked and because they have so much control over their admissions process, selection decisions, rather than a lottery, result in their yield factor.

Table 3 contains results on applications, selections, available slots and yield factors for three AVTs.

<table>
<thead>
<tr>
<th>AVT*</th>
<th>Yield Factor</th>
<th>Total Regular Education Slots</th>
<th>Number of Students Applied/Deselected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Applied</td>
</tr>
<tr>
<td>HS#1</td>
<td>400</td>
<td>245</td>
<td>1,778</td>
</tr>
<tr>
<td>HS#2</td>
<td>700</td>
<td>498</td>
<td>2,730</td>
</tr>
<tr>
<td>HS#3</td>
<td>800</td>
<td>525</td>
<td>3,328</td>
</tr>
</tbody>
</table>

*Note: High School names suppressed for confidentiality

Table 3: AVT Program Selection Results for First-Choice Applicants

This table illustrates that AVTs need to notify about twice as many students of acceptance to their programs (via a lottery) than actually register. It is possible that if all programs notified students of their selection/deselection status earlier in the assignment process, and if students were allowed to rank AVTs and SA by preference, yield factors would decrease and AVTs and SAs might be better able to gauge demand for their programs. This is a point that we revisit in the next section.
VI. Potential Information Technology and Management Science Improvements to the Student Assignment Process

There are a number of recommendations made by the author at the conclusion of the student assignment project that, though favorably received, were not implemented for the next current academic year and which may not be implemented in the near future given SDP resource limitations. We present them here to illustrate what a student assignment process is capable of.

First, note that SDP chose to create a "super-preferences" category composed of the top two inside-feeder and outside-feeder SLCs. This was done to assist parents refine their preferences and prevent the possibility of many students applying for highly-desirable outside-feeder programs they have no realistic chance of being accepted to. Note also that SAs cannot be ranked by parents, partly because these programs are so desirable that it is assumed that an acceptance to them will trump acceptances to other SLCs. Thus, students and parents have imperfect information about AVTs and SAs at the time the HSAF is filled out. This results in an assignment process perhaps excessively complex from the information management and customer service perspectives: some applicants are automatically accepted to most-desired programs after the initial lottery, others accept one of a number of competing programs after the initial lottery and still others must await the outcome of the "backfill" procedure in which students who have accepted (or been assigned to) certain programs are removed from lists of other, less-preferred programs.

If, alternatively,
- Parents and students had information on past trends in acceptance rates for a
wide variety of programs,
- It were possible, via an on-line, automated application system replacing HSAF
for students to immediately determine the criteria-based and SA programs for
which they met minimal qualifications,
then it might be possible for parents and students to construct a single list of all programs
for which they are interested, in descending order of preference. Subsequently, the result of
the first lottery process and notification by SAs of acceptances might result in a greater
number of students choosing academic programs after multiple acceptance report letters
are sent. Of course, some manual processing would be necessary to deal with students
whose applications are incomplete or missing. In addition, SDP policy that attempts to give
students their first-most-preferred program (as opposed to the most-preferred program
following, say the first re-scan of the wait lists) would again require multiple lottery
processes. Each assignment process could be performed with linear programming. We
illustrate this prototype model later in the section.

Another project recommendation not yet implemented is the creation of a fully
relational database for student information to enable the student assignment process to
handle an arbitrarily large number of preferences (i.e. \( P \) as large as necessary) and to
enable creation of an audit trail of the process for a given year (i.e. multiple lotteries) and
over multiple years. The current student information database is composed of variable-
length record tables that reside on a mainframe computer and which used COBOL to run
programs and queries. The architecture of this database is difficult to modify, system
documentation hard to find and programs and queries time-consuming to create and run; this is no less so for the student assignment lottery process.

As SDP’s Information Technology Planning Project: Information Technology Plan [School District of Philadelphia 1998a] makes clear, it is crucial that SDP adopt enterprise-wide client-server relational database applications to make the best possible operational decisions with the huge volume of data at its disposal. An example of a relational database design that could be adapted for the student assignment process based on standard IT design principles [Rob & Coronel, 1997] is shown in Figure 3. This type of database design could also be used for on-line applications for the student assignment program, something that will be difficult to implement in a traditional mainframe-based environment.

![Figure 4: Sample Entity-Relationship Model for SDP Student Information System](image-url)
An enterprise-wide client-server relational database application would also make it possible for analysts, administrators, counselors and parents to quickly access a wide variety of reports regarding (but not limited to) the student assignment process. While SDP has developed a character-based, mainframe-resident report generator called TRACKER [School District of Philadelphia, 1998b], this application offers limited flexibility in the type and format of reports, cannot send reports to local printers and, because of its mainframe orientation, may induce the perception of requiring specialized knowledge to use.

True on-demand reporting would allow end-users, with minimal training, to specify the data variables to report on, the type of analysis to be performed (e.g., cross-tabulations, averages by year, etc.) and the report format. Such an application enabling parents, for example, to determine which programs are most likely to accept their children, would enable SDP to significantly advance towards a goal of improved customer service.

Another aspect of increased availability of information regarding the student assignment process is the prospect of providing services via the Internet. One can imagine, for example, that a Web page allowing instant perusal of current student assignment program acceptance rates for various programs over various years, or on-line submission of student assignment program applications, would avoid to some degree the capital-intensive issues of network design and client-server application design to account for a large area such as the School District of Philadelphia. This information could also be accessible to parents and students from any public terminal, for example those in public libraries or community centers, rather than relying on school counselors to make proprietary applications available. Provision of information in this form would also serve
as an incentive for increased use of IT and the Internet, consistent with the recommendations of the recent report *Falling through the Net: Defining the Digital Divide* [U.S. Department of Commerce, 1999].

Yet another business issue that could be modified in the future is the issue of which applicant households receive multiple acceptance report letters after the first lottery process. As indicated in the previous section, only a minority of all parents--those whose children have been accepted into their most-preferred SLC as well as an AVT and/or an SA, or those who have been accepted into their most-preferred SLC and have been accepted to no AVTs or SAs--receive letters from SDP confirming this fact. Thus, there is the possibility of misinformation among parents who do not receive letters, or fears that their children will not be admitted to most-preferred programs. It may be possible for SDP to notify all parents of high school program applicants in writing of the status of their children’s applications, all the while ensuring them that SDP will make every effort to ensure that students are admitted to their most-preferred programs.

Finally, there are management science/operations research models that could make the student assignment program even more efficient and consistent. We first present two alternative integer programming models based on the well-known assignment problem [Woolsey, 1998]. Sets, data and decision variables are defined below:

Sets:

\[ i = 1, 2, \ldots, M \]: index of students seeking admission to various programs

\[ j = 1, 2, \ldots, N+1 \]: index of available academic programs (\( j = N+1 \) is a default open-enrollment program in the local comprehensive high school)
\[ k = 1, 2, \ldots, P: \] index of possible program rankings \((k = 1 \text{ is most-preferred}, k = P \text{ is least preferred})\)

Data:

\[ r_{ij} = \text{ranking assigned by student } i \text{ for program } j \ (r_{iN+1} = M, \text{ where } M \text{ is a large number}) \]

\[ a_{ij} = 1 \text{ if student } i \text{ has either met minimum requirements or has been approved for program } j, \]
\[ = 0, \text{ otherwise} \]

\[ I_{ij} = 1 \text{ if student } i \text{ is within the feeder pattern for program } j, \]
\[ = 0, \text{ otherwise} \]

\[ O_{ij} = 1 \text{ if student } i \text{ is outside the feeder pattern for program } j, \]
\[ = 0, \text{ otherwise} \]

\[ S^I_j = \text{available inside-feeder capacity of program } j \]

\[ S^O_j = \text{available outside-feeder capacity of program } j \]

\[ q^k_{ij} = 1, \text{ if student } i \text{ designates program } j \text{ as } k\text{th-preferred}, \]
\[ = 0, \text{ otherwise} \]

Decision Variables:

\[ x_{ij} = 1, \text{ if student } i \text{ is assigned to program } j, \]
\[ = 0, \text{ otherwise} \]
Model SA:

\[
\begin{align*}
\min & \sum_{i=1}^{M} \sum_{j=1}^{N+1} r_{ij} \cdot x_{ij} \\
\text{s.t.} & \sum_{j=1}^{N+1} x_{ij} = 1 \forall i \\
& \sum_{i=1}^{M} I_{ij} \cdot x_{ij} \leq S^I_j \forall j \\
& \sum_{i=1}^{M} O_{ij} \cdot x_{ij} \leq S^O_j \forall j \\
& x_{ij} \leq a_{ij} \forall i, j \\
& x_{ij} \in \{0,1\} \forall i, j
\end{align*}
\]

Model SA minimizes the total dissatisfaction perceived by all students as a result of program assignments (equation 1), subject to a number of conditions. Constraints (2) ensure that all students are assigned to an academic program, even if the program is a default, inside-feeder, open-enrollment program. Constraints (3) ensure that the number of inside-feeder students assigned to each program not exceed the forecast inside-feeder capacity. Constraints (4) ensure that the number of outside-feeder students assigned to each program not exceed the forecast outside-feeder capacity. Constraints (5) ensure that a student cannot be assigned to any program unless that student has met minimum requirements (for open-enrollment or criteria-based SLCs) or has been formally accepted (for special admissions SLCs, AVTs and SAs). Constraints (6) require that the decision variables be binary.

SA suffers from two flaws, however. First, objective (1), while acceptable on broad social welfare grounds, could generate assignments in which some students assigned to less-preferred programs when there may have been space available in more-desirable
programs, resulting in political opposition to the assignment scheme. Second, objective (1) does nothing to ensure that students get their first-most-preferred program, a key policy priority of SDP. The first objection could be addressed by converting objective (1) to a quadratic formulation, as below:

$$\max \sum_{i=1}^{M} \sum_{j=1}^{N} (r_{ij} \cdot x_{ij})^2$$

This new objective strongly penalizes assignments that are undesirable from the student’s point of view. Unfortunately, this quadratic assignment problem can be substantially more difficult to solve to optimality than the linear quadratic assignment problem.

The second objection could be addressed by replacing objective (1) with a new objective as below:

$$\max \sum_{i=1}^{M} \sum_{j=1}^{N} q_{ij}^1 \cdot x_{ij}$$

In this case, we maximize the total number of students who receive their most-preferred program choices. In fact, objective (8) could be extended to proportionally weight similar expressions for the total number of students who receive their second-most-preferred program, third-most-preferred program, and so on.

Because objectives (1) and (8) address very different policy needs, we could formulate a multiple-objective optimization problem, in which (1) and (8) are jointly
optimized with respect to constraints (2) – (6). Using the multiobjective programming techniques [Cohon, 1978], one could solve this problem to generate a tradeoff curve (Pareto surface), in which pairs of objective function values corresponding to alternative solutions to the multiobjective problem are displayed in a two-dimensional plot. Decisionmakers may thus select the solution that is the most-preferred compromise between the two competing objectives.

Additional analysis of model results could be performed to determine how equitable various solutions are with respect to different student groups, for example by calculating the percentage of total students who received their first-, second-, …least-preferred program options. Alternatively, the attractiveness of various academic programs could be measured by calculating, for each program, the fraction of students assigned to it for which the program was their first-, second-, …least-preferred option.

Finally, optimization models such as (1) – (6) and its variants could be used as a basis for exploratory policy analysis related to eighth-grade student assignment. For example, if distance traveled by students to various programs is an issue, another objective that minimizes the total distance traveled by students to the high schools to which they have been assigned could be analyzed, separately or in various combinations with objectives (1), (7) and (8). Alternatively, this criterion could be treated as an additional constraint to the optimization model. Using the model to explore the impacts of demographic changes might also yield useful results: additional data and constraints could be defined to enforce desegregation guidelines by program. Such a model would be useful in assessing the change in racial composition of inside-feeder and outside-feeder students by program under various modeling assumptions.
Another variant of optimization model (1) – (6) could explore the impact on teacher assignments of increased student choice: a measure of teacher reassignment costs given student assignments to programs that are significantly below capacity could be implemented as a constraint on the total costs of student assignment schemes, or as an objective to be minimized. It is even possible to imagine formulating a model similar to (1) – (6) to be used to minimize teacher dissatisfaction with classroom assignments from year to year!

Whatever optimization model is chosen for analysis, the result is likely to be increased insight into the range of values for important policy metrics as measured by decision variables such as student assignments to programs (or teacher assignments to programs).

VII. Conclusion

In this paper we have examined a policy change by the School District of Philadelphia associated with eighth-grade student assignments to high school academic programs that (1) intersects a number of different strategies as contained in SDP’s Children Achieving and Information Technology Plan initiatives, (2) requires knowledge of a variety of functional areas in education, management information systems, business analysis and policy analysis and (3) may result in a significant new emphasis placed by SDP on business principles such as customer satisfaction and analysis of market demands.

The modified eighth-grade student assignment process has resulted in a number of useful organizational and policy insights. First, we have seen that by providing detailed information on and choice regarding high school academic programs to students and
parents, students will be encouraged to improve their academic performance to enable acceptance to most-desired programs, and schools will be encouraged to design more popular programs and discard unpopular ones. Second, SPD’s increased focus on customer service via the student assignment process will require significant rethinking of fundamental business processes and the information technology infrastructure that supports these processes. In particular, business processes should focus on assessing customer needs and preferences and designing products that match these needs and preferences. In addition, IT infrastructure should support enterprise-wide, on-demand analysis of data, based on well-organized and flexible data structures. Third, there is an increased need for interdisciplinary teams that cross traditional functional boundaries in order to address bottom-line customer concerns. In sum, SPD is similar to public housing agencies and other government bodies in realizing that it has to increasingly act like a business in order to retain customers and, more importantly, retain confidence in the public good represented by public education.

We have presented a number of important changes to the eighth-grade student assignment process, some of which have been implemented and others of which may form the basis for research, at least in the short term. Key implemented changes include: design of key business processes as a flow chart and time line, redesign of high school application form and redesign of student assignment and lottery process. Important areas of research and development include: design and implementation of a fully relational database for student information, increased enterprise-wide networking and Internet connectivity for various real-time applications, and design and implementation of optimization models for both short-term decisionmaking and longer-term policy analysis.
Acknowledgements

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References


http://www.philsch.k12.pa.us/adm/Children_Achieving.

-------------------------------------------. (1998a). Information Technology Planning Project:


Appendix I: Draft of a Single-Form High School Transfer Process

Diagram showing the flow of processes for transferring high school students, including steps such as sending forms to schools, checking admission forms, and reviewing equity. The diagram includes timelines and decision points for various processes such as application review and student assignment.